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Designing a Gas Test Loop for the Advanced Test Reactor

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INTRODUCTION

The Generation IV Reactor Program and the Advanced Fuel Cycle Initiative are investigating some new reactor concepts which require extensive materials and fuels testing in a fast neutron spectrum. The capability to test materials and fuels in a fast neutron flux in the United States is very limited to non-existent. It has been proposed to install a gas test loop (GTL) in one of the lobes of the Advanced Test Reactor (ATR) at the Idaho National Laboratory and harden the spectrum to provide some fast neutron flux testing capabilities in the United States. This paper describes the neutronics investigation into the design of the GTL for the ATR.

DESCRIPTION OF THE ACTUAL WORK

The minimum fast flux desired is 1.0 x 10^{15} n/cm^2-s and a minimum fast to thermal ratio of 15 as defined in the Gas Test Loop Technical and Functional Requirements. Neutrons having an energy greater than 0.1 MeV are considered to be fast neutrons in this study. The thermal range is anything below 0.625 eV.

Concepts considered for increasing the fast flux and decreasing the thermal flux include: increased lobe power, adding more fuel (booster fuel) to the ATR lobe inside the driver fuel, hafnium neutron filters, and various combinations of the preceding variables. It is critical that the other lobes of the ATR remain usable in their current configurations at their current power levels while the lobe with the GTL is operated at a higher power level but within current power limits of operation.

Booster fuel concepts considered pin type fuels, thick annular slabs, and plate type fuels. Coolants included light water, helium, and sodium. The pin type fuel configurations used UO_2, UN, and MOX for the meat in the analyses at pin diameters ranging from 0.5 cm to 0.9 cm. The thick annular slab considered DU and natural uranium in metallic form. The plate fuel models used UAl_x and U_3Si dispersed fuels for the meat. The gram loading of the uranium in the dispersion, the meat thickness, and the enrichment were varied in the plate fuels while the enrichment only was varied in the pin type fuels.

The determination of the peak fast flux, the fast to thermal neutron ratio, the neutron spectrum, and the heat generation rate for the various GTL concepts were determined using the Monte Carlo N-Particle computer code revision 4C. Preliminary scoping calculations provided a means of evaluating the many different concepts under identical conditions and were used to narrow the concepts to those most promising for more detailed evaluation.

RESULTS

The analysis showed that the intensity of the fast flux was highly dependent on the power of the whole ATR core and not just the GTL lobe power as would be expected. Keeping the driver fuel power down to acceptable levels in the GTL lobe and the other lobes at their typical powers requires the use of a booster fuel to increase the fast flux to a level at or above 10^{15} n/cm^2-s. Increasing the lobe power alone is not enough to achieve the desired results.

Of the booster fuel designs considered, the pin type fuels were quickly eliminated based on their high linear heat generation rates at the powers needed to boost the fast flux up to 10^{15} n/cm^2-s. The linear heat generation rates ranged from about 20 kW per foot to 30 kW per foot which exceeds the heat rate at which they are designed to operate.

The DU and LEU annular slab models could not meet the minimum requirements specified in the technical and functional requirements while maintaining the other lobes at their normal power levels. Thus the remaining option was plate type fuel with either aluminide or silicide meat enriched to 93% U-235. Loading enough fuel in the small area led to the conclusion that silicide meat was the best choice for the fuel since its capabilities are well know up to loadings of 4.8 gU/cc. Staggering the fuel loadings and thickening the meat in the plates combined with a hafnium neutron filter provided for a controllable configuration while meeting the specifications. The latest design shown in Figure 1 provides a fast flux of approximately 1.05 x 10^{15} n/cm^2-s and a fast to thermal ratio of about 23 averaged over 16 cm in the three 1 inch tubes.

CONCLUSION

Preliminary analysis indicates that the initial concept of modifying one lobe in the ATR to produce a simulated fast reactor spectrum is feasible. In order to achieve the technical requirements for future research, however, the analysis also shows that booster fuel is needed. Further development work on the fuel and detailed design work is continuing.

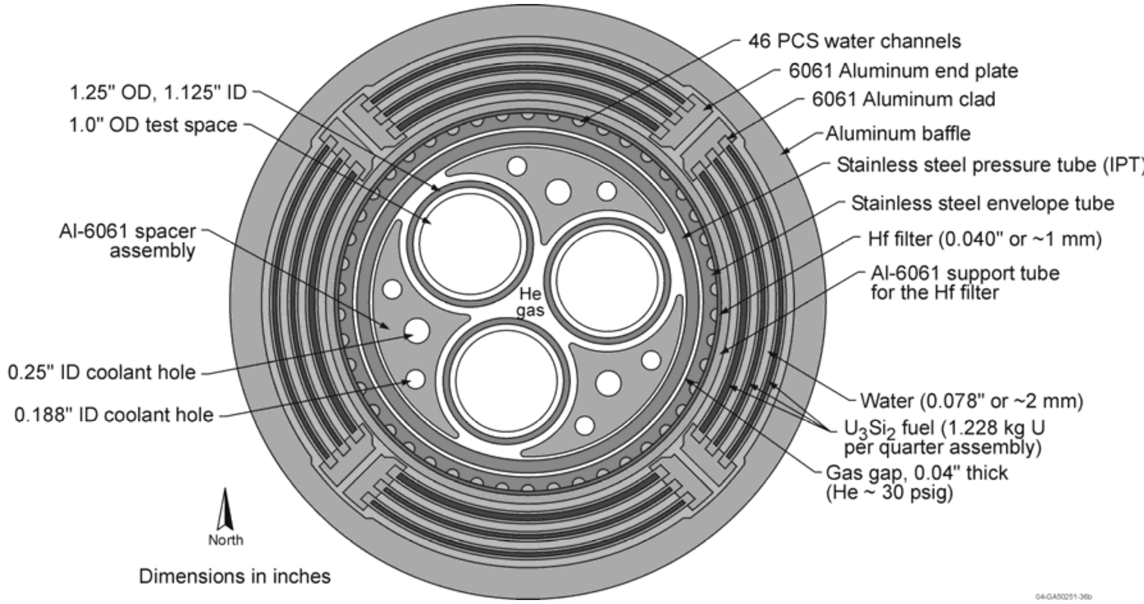

Fig. 1. A graphical representation of the Gas Test Loop conceptual design.